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Conservation relevance of bat caves for biodiversity and ecosystem services

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ABSTRACT

All ecosystems are dotted by salient small natural features that not only characterize them but also significantly add to their biodiversity and functions. These small natural features are prominent but easily missed when ecosystems are described. Caves are one key example of this. Cave ecosystems are underrepresented in conservation planning and implementation around the world and have become mostly overlooked in conservation strategies overall. Caves contain high levels of biodiversity from fungi to invertebrates to vertebrates. This paper emphasizes bat caves as providers of ecosystem services to vast areas surrounding them, in the order of hundreds of thousands of square km just in North America. Their influence extends three-dimensionally via subterraneous water bodies and via the aerial nightly dispersal of the bats that provide a host of services from seed dispersal to pollination to pest control. The examples used focus primarily on free-tailed bats in North America, but the same principles apply to any other cave in the world with significant bat colonies. Caves enjoy protection, legal or actual, in some countries and not in others, and as a result many have suffered damage or been destroyed altogether. Common threats are vandalism, urbanization, and pollution. Many caves are attractive as ecotourism destinations and provide unique opportunities to educate the public about unexpected biodiversity values and ecosystem services. Inventorying caves poses challenges, but efforts are under way to assess caves in need of protection. Incipient cave protection strategies include legal and educational efforts, and management. Although illustrated with bat caves, given the importance of all caves and their precarious status, it is time to call the attention of decision makers about the urgent need to launch a worldwide cave conservation initiative.

1. Introduction

1.1. Defining caves

The definition of a cave has been the subject of significant debate. Their origin, configuration, scale, contents, and other issues have been considered, and no single definition has been accepted (Curl, 1964; Culver and White, 2004). For purposes of this paper, caves are defined as subterranean cavities in a variety of strata, harboring significant levels of biodiversity. Most of our discussions deal with bat caves, given the very strong association between the two, although the importance of caves is also illustrated through other biodiversity. Because of this focus, we define bat caves as those that are customarily used by bats as roosts. Many substrates can contain caves, but for practical purposes of the discussions in this paper we refer to three major substrates as containing caves (Culver and White, 2004): 1) karst dissolution caves: underground spaces with an opening to surface, in limestone or dolomite; 2) sandstone caves: also underground spaces, formed by dissolution or aeolic erosion in that type of rock; 3) volcanic caves: lava tubes, bubbles, or vents. We do not include in this paper sea or glacial caves. We illustrate the value of bat caves focusing on caves harboring Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) given the relatively robust amount of literature on them, but the same is applicable to many other caves across the world, in temperate and tropical areas containing many species of bats. Although the regional impact of these caves in other areas of the world has not been modeled, evidently the principles herein described are clearly applicable to all other caves with significant bat populations.

1.2. Why are caves important?

We have all seen them, from giant trees to small ponds and streams, to kopjes, boulders, creeks or caves. But these small natural features, sites with ecological importance that is disproportionate to its size (Hunter, 2017) are rarely if ever considered when an ecosystem is described. An extreme case of these overlooked but deeply influential features are caves. Caves are relatively small to tiny landscape features that dot huge regions of the world. Few cave maps are available and proportionally, considering the hundreds of thousands of caves in the world,

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caves are considered protected areas only in some areas such as Europe, Puerto Rico, certain caves in Canada, certain states of the U.S.A., Australia, the Philippines, and few more (e.g. Fitzsimons and Ashe, 2003; Boulton et al., 2003; Whitten, 2009; Zhalov, 2015). Given that most conservation assessments and landscape analyses are based on vegetation cover, forest fragmentation, and other above-ground ecosystem features, subterraneous ecosystems tend to be underrepresented or ignored in conservation plans and protected areas (Sugai et al., 2015). Caves are reservoirs of exceptional levels of endemic and threatened species (Deharveng, 2005), very high levels of genetic uniqueness (Gibert and Deharveng, 2002), and they harbor unconventional taxa such blind fish, crustaceans, insects, worms, and many other groups (Gunn, 2004). In just the contiguous 48 states of the U.S., at least 927 species in 96 families are troglobites (obligate cave dwellers), but only 4% of those species enjoy any level of federal protection (Culver et al., 2000). Lack of adequate consideration of cave ecosystems in biodiversity conservation efforts has been pointed out repeatedly (Langer, 2001, Sugai et al., 2015).

The influence of caves on the surrounding ecosystems is also large. Given the numerically enormous concentrations they form inside, once bats emerge they must travel long distances in order to find food. The movements of bats are associated with their predation pressure on insects, particularly insect pests. A very conservative estimate of nightly movements of 50 km from the cave roosts of Mexican free-tailed bats was published by Williams et al. (1973). These bats are able to easily fly much farther distances, given that they are long-distance migrants and the fact that they are the fastest flying animals (horizontally) on earth at 160 km/h (McCracken et al., 2016). If we adopt 50 km as a benchmark, then the area of influence of bats around each of their caves can be conservatively estimated at about 7850 km^2 (Fig. 1). Applying this to all 29 Mexican free-tailed bat roosts listed in Table 1, another underestimate given that only a fraction of the bat caves are known in this region, the total area influenced by these 19 small natural features in the landscape amounts to almost 150,000 km^2.

Although many people associate all bats with caves, only about half of Mexico's 138 bat species live in caves (Arita, 1993, Medellin et al., 2008). In other countries the percentage varies; for example, 77% of the bat species in China live in caves (Luo et al., 2013), 80% of those in Puerto Rico (Ladle et al., 2012), and 23 out of the 33 bat species in Bohol island in the Philippines live in caves (Phelps et al., 2016). Other bats live in large old trees, or in rocky outcrops (Lindenmayer, 2017; Fitzsimons and Michael, 2017), in tents built by them out of large leaves in tropical forests (Rodríguez-Herrera et al., 2007), and in a variety of other natural and anthropogenic roosts (Fenton and Simmons, 2014). Bats form some of the largest warm-blooded vertebrate concentrations in the world and their biology is widely diverse (Medellin et al., 2008). By focusing only on a single, fairly well-known species, the Mexican free-tailed bat and the ecosystem services they provide, the importance of caves for ecosystem functioning and for human well-being becomes obvious. Mexican free-tailed bats suppress pests on important agricultural crops such as cotton and corn in Mexico and the United States (López-Hoffman et al., 2014) and also provide extensive ecotourism opportunities (Bagstad and Wiederholt, 2013). For example, by modeling the importance of caves to the viability of Mexican free-tailed bat populations (Table 1; results discussed in detail in Wiederholt et al., 2013), we determined that caves in the southern part of the summer range, those in Texas and northern Mexico, are crucial for maintaining bat population viability. Several maternity roosts in this area also had the largest summer population sizes (Wiederholt et al., 2015). In terms of ecosystem services, the roosts with the highest annual ecosystem service values (>$1 million) were all found in Texas, U.S. (Table 1). For instance, the value of the pest suppression activities of the bats residing in Bracken Cave, Texas, is $3.42 million per annum, followed by Frio Cave, Texas ($2.42 million). The total annual ecotourism value of a subset of cave viewing sites of Mexican free-tailed bats in the southwestern U.S. was conservatively valued at $3.95 million (Bagstad and Wiederholt, 2013). The site with the highest ecotourism value was Carlsbad Caverns National Park, with $3,477,072 (Table 1).

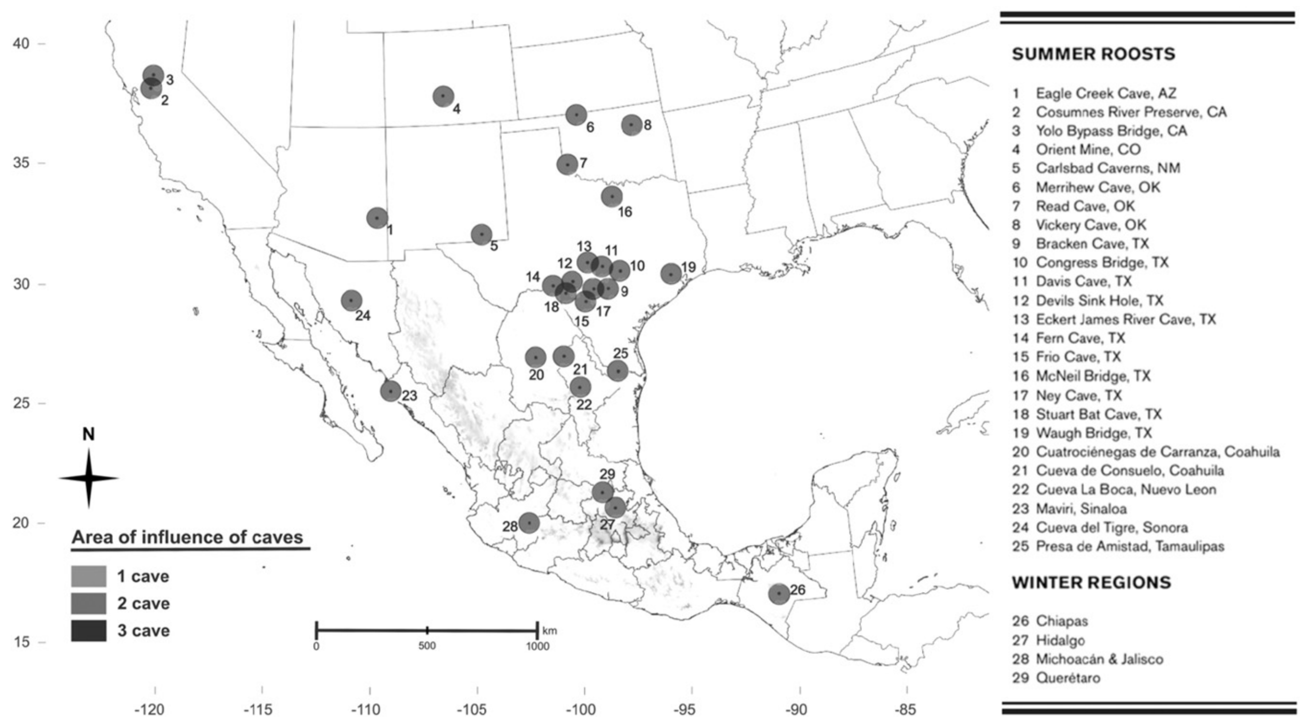

Fig. 1. The 29 roosts (mostly caves) of Mexican free-tailed bats known to date, with their conservative 50-km radius buffer of influence area. Total area covered by these caves adds up to almost 150,000 km^2. The known Winter regions are highlighted in purple (western Mexico), red (central Mexico), blue (Eastern Mexico), and orange (southern Mexico). Data from Wiederholt et al., 2015.